Work schedules and sleep

by T. Åkerstedt

Stress Laboratory, Karolinska Institute, and National Institute for Psychosocial Factors and Health, S-10401 Stockholm (Sweden)

Introduction

Work schedules disturb sleep mainly if they interfere with the normal night sleep hours. There is a great variety of such interfering schedules and the taxonomy is far from clear cut. Yet, it is possible to discern at least 4 types of schedules: permanent night work, 3-shift work (regular alternation between thirds of the 24 h), roster work (less regular and less strict 24 h coverage) and irregular work hours. Frequently the 4 types of schedules are collectively referred to as 'shift work'. This is clearly a misnomer but will still be used here for lack of alternatives.
The amount of people engaged in shift work is not known exactly but Maurice[58] estimates the figure to about 20% in industrialized countries. Since, as will be discussed below, most individuals in shift work suffer from deranged sleep, shift work must constitute a major source of sleep disturbances in industrialized countries. This paper will review the effects of work schedules on sleep and fatigue and how these effects may be brought about.

Sleep disturbances

The estimated percentage of individuals suffering from sleep disturbances varies greatly depending on the method of estimation. It ranges from 10% to 90% (usually above 50%) for shift workers, and from 5% to 20% for day workers[1,13,14,41,48,52,56,61,68,70,82]. Also sleep length estimates vary greatly from study to study but usually range from 4 h to 6 h for those doing night work, compared to the 7–9 h for those doing day or afternoon work[1,9,17,49,66,69,70]. The table summarizes more detailed data from our study of 1000 Swedish train engineers working irregular schedules[11]. It shows that sleep problems occur mainly in connection with night work but also to some extent in connection with morning work. Particularly frequent after post-night-work sleep, are feelings of not being fully rested. Sleep after this shift is very short, and is apparently due more to an inability to maintain sleep rather than to difficulties in falling asleep. Reports of noise-disturbed sleep are somewhat more frequent after the night shift than after other shifts but the percentage figure is low in comparison with the proportion of workers claiming that they do not feel well rested. It is noteworthy that also morning work causes difficulties. This may be due to anticipation of the very early rising needed (approximately 05.00 h) to start work.
Several studies have attempted to objectively verify the survey data. Among the first were Foret and Lantin[35] who studied train engineers at different phases of their very irregular schedule. The recordings were made at home and in dormitories. The major result was that total sleep time (TST) depended on when the individual went to bed, i.e. TST decreased from a maximum of 10–11 h after going to bed at 23.00 h to only a few hours sleep after going to bed at noon. The relative amount of slow wave sleep (SWS) did not vary between bedtimes, whereas that of rapid eye movement sleep (REM) reached a maximum in the morning.
Foret and Lantin's study was naturalistic and described the total impact of the environment on sleep. Thus, the 24-h sleep pattern included intentional naps, sleep disturbed by dormitory environment, and sleep that was terminated by a new work assignment. To obtain information on sleep under more favorable circumstances, we monitored sleep in engineers only when optimal conditions could be assured[75]. This meant making recordings only in homes with a good sleep environment and when there would be no post-sleep work assignment to interfere with the spontaneous course of sleep. The results turned out to be very similar to those of Foret and Lantin. Night sleep after day work was 8.0 hours and day sleep after night work was 4.3 hours. Practically all of this reduction was due to reduced stage 2 and REM sleep (fig. 1). Adequate amounts of SWS was usually accomplished by the time sleep was terminated. Awakenings occurred spontaneously in all but one case (i.e. no external causes were reported). This is supported by the fact that the rated alertness on rising was high. Interestingly, both adrenaline and noradrenaline excretion during day sleep correlated negatively with TST and positively with sleep latency and the number of stage changes. Before awakening had occurred rectal temperature had begun to rise sharply, which was not the case during night sleep.
Tilley et al.[73] studied industrial 3-shift workers on a rapidly cycling schedule. As in the previous study, sleep was recorded in the home environment and was ad libi-

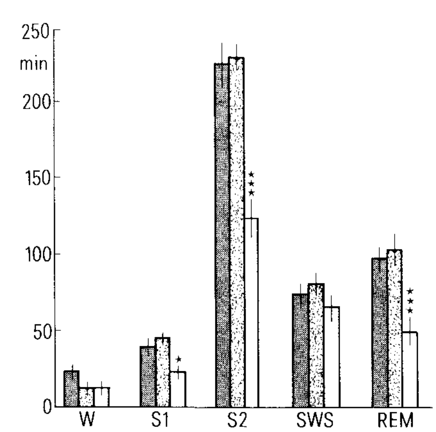

Figure 1. Amount of time spent in stages wake (W), 1, 2, SWS (3 + 4), and REM during 2 night sleep episodes (shaded) after day work and 1 day sleep episode after night work. Night sleep began at 23.03 h and day sleep at 07.35 h (means). * $p < 0.05$ and *** $p < 0.001$ for the difference between day and night (both) sleep. N = 16.

tum. Sleep length after the night shift amounted to 5.1 h, after the morning shift to 6.0 h and after the afternoon shift to 7.0 h. During the short sleep period after the night shift the amounts of stage 2, REM and SWS were reduced, as was sleep efficiency. Also the sleep architecture was changed such that both REM and SWS showed more level patterns instead of the characteristic rise and fall respectively during normal night sleep.

Additional studies of shift workers' sleep have been carried out in various laboratories; they have yielded results similar so those mentioned above[26,32,33,57]. Thus, sleep after a night shift seldom exseeds 6 h length and usually contains less REM and stage 2 sleep. Sometimes SWS and sleep efficiency also may be reduced, although this does not seem to be the rule. In most studies REM but also SWS patterns during sleep become more level. As may have been expected, a gradual adjustment has been found over successive night shifts[26,33], although the change has been very small.

It should be mentioned that shift workers often compensate for lost sleep in various ways. Tune[76], e.g., has found that the total amount of sleep obtained during a shift cycle may exceed that found over a corresponding period of day work. This is partly due to increased napping[12], partly to extended sleep during days off[8], and partly to the extended sleep in connection with the afternoon shift as indicated in most of the studies cited above.

Workers on permanent night work would presumably exhibit a better adjustment of sleep than workers on alternating work hours. To some extent this expectation seems to be borne out. In a study of experienced and committed night workers, post-night shift sleep varied between 5.9 and 5.1 h over a week against 7.0 h of night sleep during days off[26]. Remarkably, TST decreased over the night work week. A comparison with rotating shift workers showed a greater day-to-day consistency for the permanent night workers. Few other differences were found except that stage REM appeared somewhat early. Two other studies of established and committed night workers[55,78] and three studies of temporary night workers[21,27,53] essentially confirm the study by Dahlgren[26].

A somewhat exceptional work schedule situation faces airline crews. They frequently work nights but, in addition, often traverse several time zones. Thus, not only the sleep/wake pattern is altered but also the light/dark pattern and other environmental 24-h conditions. Several questionnaire studies have shown that subjects have difficulties in maintaining day sleep after, e.g., transatlantic flights[2,54,63,64]. If the meridian crossing is continued on a world-wide schedule, sleep deficits cumulate with the increasing number of days away from base. EEG studies of sleep after transmeridian travel have produced variable results[28-30,46]. Mostly, however, sleep has been found to be more fragmented and REM sleep to be reduced but more level over the course of the sleep periods. Sometimes shortened sleep and increased SWS may be seen. The adjustment to the new sleep hours appears to be very rapid: normal sleep reappears after a few days.

Fatigue

A major effect of the sleep disturbances reviewed above is fatigue. General fatigue is usually reported more frequently by shift workers than day workers[13,41,59,72,82]. Fatigue is maximal in connection with night work. In monotonous jobs fatigue may reach levels at which sleep overcomes the individual during work[11,51,65]. That shift work (involving night work) actually causes the fatigue is also evidenced by the fact that the latter decreases if the night shift is eliminated[8], and increases with increased experience with shift work[77].
Very few studies have used physiological indicators of fatigue/sleepiness in shift workers. In a recent study we tried to quantify sleepiness in train engineers by using ambulatory EEG recording and spectral analysis[74]. Figure 2 shows the compressed spectral array of a day and night run respectively. The day run shows primarily beta activity except for a few snack-induced artefacts in the lower frequency range. In contrast, the night run over the same segment reveals repeated bursts of activity in the alpha range, particularly towards the end of driving. Most of this increased alpha activity is related to the increased duration of eye blinks. The figure also shows group mean values of the development of spectral power in the alpha (8–12 Hz) and theta bands

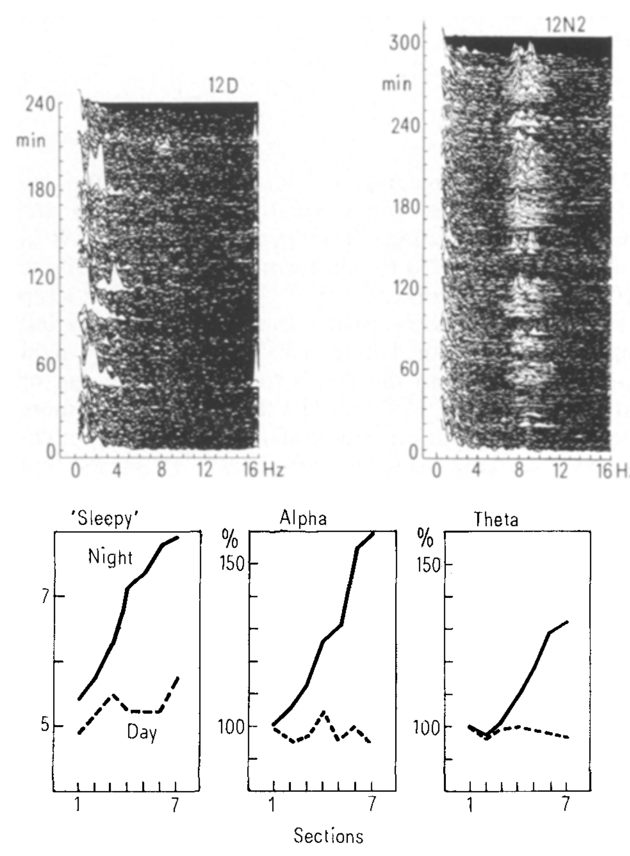

Figure 2. Upper part: compressed spectral array (FFT) from the EEG (O_2–P_4) of a train driver during a day run (left) and a night run (right) starting at 07.22 h and 22.33 h respectively. Lower part: Mean values during day (– – –) and during night (——) driving from 15 train engineers. Lower left: self rated sleepiness. Lower middle and right: percent change in the alpha (8–12 Hz) and theta (4–8 Hz) bands, respectively. Each run is divided into 6 approximately equal sections with 1 indicating the point of departure.

(4–8 Hz). During the night runs there is a steep increase in both bands, whereas the day runs exhibit no change. Rated sleepiness followed a pattern parallel to that of the alpha and theta bands. Low levels of rated alertness during night work have been demonstrated in several other studies[7,26,36,37].

The fatigue in the night would be expected also to have performance consequences. In fact, reaction time is increased on the night shift[73] and the capacity for mental arithmetic is reduced[71]. More importantly, however, on-the-job performance may be affected, particularly in occupations in which operator performance is a major determinant of output. Thus, during night shift work the response speed of telephone operators is lowered[20], meter readers' accuracy deteriorates[18], train engineers' failures to respond to an alerting signal increase[44], and single-vehicle truck accidents increase[42,43].

Fatigue in connection with rapid transmeridian travel is well established and frequently takes the form of out-of-place occurrence of severe sleepiness[23,30,67]. No studies on actual flying performance have been carried out but pilot performance in a flight simulator has been found to be clearly impaired[45]. The sleep and fatigue problems in connection with rapid transmeridian air travel have led to attempts to set up equations to calculate the load of a particular work schedule. Thus, Geratewohl[38] adds travel time, a departure time coefficient, the number of time zones traversed, an arrival time coefficient, a geodirectional coefficient, and an age coefficient, to arrive at a load estimate. Other equations ave been suggested by Mohler[60] and Nicholson[63].

The mechanism

A rather frequently suggested cause of the shift workers' disturbed day time sleep is environmental interference, such as noise[48,52,72]. In laboratory experiments Knauth and Rutenfranz[47] and Knauth et al.[50] have demonstrated that noise from, e.g., traffic or from playing children will both shorten sleep and interfere with its stage composition.

Clearly, noise will interfere with sleep if it is loud and frequent enough; the probability of interference is clearly higher during day time sleep. Still, it has not yet been shown that noise is a major cause of disturbed sleep in shift workers. Several of the EEG studies of day sleep mentioned previously were carried out under noise-free conditions and yet showed pronounced sleep disturbances. Also, reports of disturbed sleep do not seem to correlate with poor housing conditions[1,9].

An alternative or additional explanation is circadian rhythmicity. We have studied this phenomenon in the laboratory with 6 subjects who went to bed at different times of day – 23.00 h, 03.00 h, 07.00 h, 11.00 h, 15.00 h, 19.00 h, and 23.00 h. The conditions were separated by 1-week intervals and involved continuous wakefulness ranging from 16 to 40 h. The subjects were isolated from environmental time-of-day cues and were instructed to sleep as long as needed, i.e. all sleep termination was spontaneous. The latter is of major importance since any sleep restriction will make results difficult to interpret.

Figure 3 shows the TST following the different bedtimes[3]. As sleep is postponed from 23.00 h towards 11.00 h sleep length decreases by more than 3.5 h in spite of the fact that the amount of prior time without sleep increases from 16 to 28 h.

When sleep is postponed past noon, TST starts to increase again and reaches a maximum at 19.00 h. The pattern gives clear evidence of the circadian influence. The right hand part of fig. 3 is a recalculation of the left figure, in order to show the sleep termination propensity. It simply depicts the proportion who terminates sleep within 6 h, plotted at bedtime +5 h. Clearly, the tendency to wake up is strongest around noon and weakest during the night hours. Most of the variation of TST was due to a corresponding variation in stage 2 and REM sleep. SWS was not affected but seemed to be finished before sleep was terminated. Figure 3 shows the characteristic within-sleep development of SWS and REM. The former always starts at a high level and falls steeply, irrespective of the time of day, whereas the latter rises after bedtimes in the afternoon and night but falls after morning or noon bedtimes.

The TST pattern in our study corresponds to that found in desynchronized subjects during long-time isolation and ad libitum sleep[24,83]. In those studies, sleep was related to the circadian phase of the body temperature instead of time of day. The results showed maximum sleep coinciding with minimum temperature. We drew essentially the same conclusion from our own data[39]. Whether the correlation between TST and body temperature involves any causal link is not known, but it should be emphasized that the maximum propensity

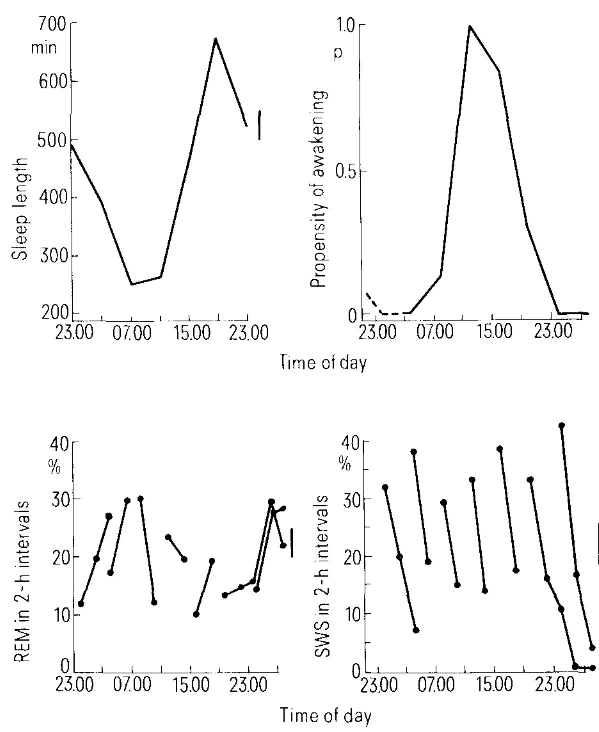

Figure 3. Results from an experiment with displaced sleep. Upper part: mean TST plotted at the respective bedtimes (left) and the propensity to wake up (right), computed as the proportion waking up within 6 h and plotted at bedtime + 5 h. Lower part: mean percent SWS and REM in successive 2-h intervals of each sleep episode. Vertical bar denotes maximum SE; N = 6.

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Percentage of subjects who experience sleep difficulties often or sometimes in relation to day work (starting around 08.00 h), morning work (06.00 h) and night work (23.00 h). Also, sleep length for corresponding work hours; N = 1000

	Day	Morning	Night
Difficulty of falling asleep	5	26	29
Difficulty of maintaining sleep	9	32	54
Not well rested	9	41	61
Noise disturbances	2	10	22
Sleep length	7.6 h	5.7 h	4.3 h

to wake up also coincides with maximum subjective alertness[3] and maximum adrenaline excretion[6]. The agreement between our study and the isolation studies also extends to the sleep stage patterning – SWS is seldom affected by the time of day whereas REM is clearly enhanced during a few hours in the morning.

The data thus far agree very satisfactorily with the data from shift work studies and from the laboratory experiment on day sleep by Benoit et al.[15]. The majority of laboratory experiments, however, have failed to confirm the early termination of day time sleep[16,22,47,50,79,80,81]. The reason for the discrepancy is not clear, but compared to the shiftwork studies and the laboratory experiments done by Benoit et al.[15] and ourselves[3] other laboratory experiments have used much younger subjects as well as a restricted time-in-bed (usually 8 h). Both would be expected to increase sleep length; day sleep ability deteriorates with age[10,34] and forcing a fully alert and well rested person to remain in bed will induce unnecessary sleep[31,62].

Even if the circadian impact on sleep/wake regulation is pronounced, one should not overlook the fact that also sleep loss plays an important role. In a recent laboratory study (in preparation) with 8 male subjects (age 19–45) we found that day (11.00 h) sleep parameters were a direct function of the amount of sleep during the prior night. Thus, total sleep loss yielded 4.5 h of day time sleep, whereas a full night's prior sleep yielded 1.5 h. SWS increased with prior sleep reduction and REM decreased. The effect of sleep loss is also obvious in our study of the circadian pattern of sleep[3], mainly as longer-than expected evening sleep. Recently, Borbély[19] and Daan and Beersma[25] constructed a model for sleep/wake regulation which adds together the effects of circadian (C) and homeostatic sleep (S) factors. This largely accounts for the sleep/wake patterning both in connection with displaced sleep under normal sleep/wake condition and in connection with desynchronization in isolation studies.

The fatigue/sleepiness in connection with shiftwork may also be explained by the model above. When sleep loss persists over several days a circadian oscillation of sleepiness is clearly superimposed on an almost linear day-by-day increase[5].

To simulate the development of sleepiness in shift workers we postponed night sleep for 6 male subjects to the morning and terminated it after 4 hours. Before and after sleep a number of sleep latency tests were carried out. The results showed that the short day time sleep was followed by a decrease of sleep latencies superimposed on the normal circadian increase towards the evening[4], i.e., the usual evening rise of alertness was suppressed.

In *summary,* the data available demonstrate that work schedules interfering with conventional sleep hours are associated with disturbed sleep. The latter involves both a shortening of sleep as well as a rearrangement of the sleep architecture. The main reason for the disturbed daytime sleep is the influence of a circadian 'arousing' factor which starts its upswing at about the same time as the shift worker goes to bed after a night shift. These sleep disturbances, together with the night time circadian minimum, account for most of the fatigue reported by shift workers. It should also be mentioned that there is no objective evidence for any (negative) long term effects of the repeated sleep disturbances. Neither is there any objective evidence to indicate that one schedule (of those discussed) should be preferred to any other. Both these questions are important areas for future sleep research on work schedules.

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To what extent can sleep be influenced by diurnal activity?

by J. Foret

Laboratoire de Physiologie Neurosensorielle CNRS, 15, rue de l'Ecole de Médecine, F-75270 Paris Cedex 06 (France)

There are various pieces of evidence suggesting that daytime activity has an influence on the subsequent period(s) of sleep: first, there is everyday experience which has shown that some kinds of activity favor sleep, while others are detrimental to it. In every language, there is a score of books dealing with «What to do to enjoy a good-or-better-sleep». Second, we have data, more or less documented, obtained in laboratories by means of physiological and psycho-physiological studies. Almost all of these studies have been carried out in order to prove an hypothesis concerning the roles of sleep, sleep's internal architecture or of REM-sleep.
One can classify the data in the following groups:

1. The SWS-exercise hypothesis

Because there is no doubt that during sleep the body is recompensated for the physical exertion during the day, it has been hypothesized that sleep is associated with a process of restoration and even that 'sleep is for restoration'[2]. In addition, energy conservation resulting from the lack of movement during sleep has been widely documented and has led to the hypothesis that one role of sleep would be to allow (or force) that immobility. To date this approach has been documented by many phylogenetic and ontogenetic studies (e.g. Horne[19]). But it must be kept in mind that bedrest without sleep can by no means replace sleep[23]. Of course, these conclusions refer to average results which required that animals or humans were placed over a long period in stable, standard situations. Thus, if the conditions of diurnal life are, at least for a short period, abruptly modified relative to the lifespan of the animal (for instance by means of setting an activity rate above the usual, regular level), modifications of sleep can be expected.

2. Phylogenetic data

The phylogenesis of internal sleep architecture has shown that some sleep characteristics are linked to the metabolic rate of the species[17,37]. The average sleep duration seems to be positively correlated with the metabolic rate; the duration of REM-sleep is negatively correlated. Therefore, the assertion that sleep is a function of metabolism, that is, of total energy consumption, leads to the conclusion that an abrupt modification of the diurnal environment must change energy demand and thus finally alter sleep patterns.

3. The chronobiological approach

This has, to date, abundantly documented the temporal interdependency of most of the physiological variables. In this respect, a 'map' of mutual phase relationships among the acrophases (i.e. estimated peaks) of secretion of a variety of neuroendocrine variables can be designed. Under normal circumstances their time courses appear to be more or less tightly correlated to schedules and characteristics of sleep.
At the present time, very little is known about the functional significance of those temporal relationships. In particular, it is generally impossible to obtain evidence of causality of such relationships. However, if the diurnal time course of some endocrine variables is artificially modified, for instance by means of an intense physical demand or forced abnormal times of feeding, other variables are likely to be modified (e.g. HGH)[5,26] which in turn would alter sleep characteristics.
At any rate, in order to study how the environment influences sleep, it is first necessary to define 'normal diurnal activity'. Taking into account the practical impossibility of coming up with such a description, it would seem somewhat paradoxical to publish a quantitative description of 'normal' human sleep[36]. In contrast, studies carried out in animals such as the Papio showed that important ecological modifications resulted in significant and lasting changes in sleep patterns within the same species[8,9,28].
For the human species every attempt to describe a standard environment seems to be futile. Within a single industrial society for instance, there are huge differences in the daily energy expenditure, and therefore in the nu-